Project 1: Robot Path Planning

Group Members: Anna Teng, Sunny Li

Program Running Instructions:

Program should be run via the terminal with 4 arguments being the python file containing the project code, input file path, k, and output file path in the format: **python3 <robot_path_finding_code_file> <input_file_path> <k_value> -o <output_file_path>**.

For example, with input 1 and k of 0:

python3 RobotPathPlanning.py "Inputs/Input3.txt" 0 -o Output3.txt

There are also 3 folders in the same directory as the code file that we utilized when making/testing the project:

1. Inputs: stores all the inputs
2. Outputs: the folder the outputs are generated to
3. Logs: stores all logs generated during testing

Program Source Code:

```
"""
Robot Path Finding Project
Authors: Anna Teng, Sunny Li
"""

import os
import logging
import heapq
import math
import copy
import argparse
from datetime import datetime


DIRECTIONS = [(1, 0), (1, 1), (0, 1), (-1, 1), (-1, 0), (-1, -1), (0, -1),
(1, -1)]


# Set up logging configuration
def setup_logging(input_file_name, output_file_name, k):
    os.makedirs('Logs', exist_ok=True)
    timestamp = datetime.now().strftime("%Y%m%d_%H%M%S")
    log_filename = os.path.join('Logs', f"{timestamp}.log")

    logging.basicConfig(
        filename=log_filename,
        level=logging.INFO,
        format='%(message)s'
    )
```

```
    logging.info("========= A* Search Run Log =========")
    logging.info(f"Input File: {input_file_name}")
    logging.info(f"Output File: Outputs\\{output_file_name}")
    logging.info(f"k: {k}")
    logging.info("====================================\n")


# OutputModel class to simplify the code relating to the output
class OutputModel:
    def __init__(self, output_dict: dict):
        self.depth = output_dict["depth"]
        self.generated_nodes = len(output_dict["generated_nodes"])
        self.moves = " ".join(map(str, output_dict["moves"]))
        self.f_values = " ".join(map(str, output_dict["f_values"]))

        rows = [" ".join(map(str, row)) for row in output_dict["workspace"]]
        self.output_workspace = "\n".join(rows)


# Node class
class Node:
    def __init__(self, pos, path_cost, total_cost, last_angle=0,
parent=None):
        self.pos = pos
        self.path_cost = path_cost
        self.total_cost = total_cost
        self.last_angle = last_angle
        self.parent = parent

    def __lt__(self, other):
        # Used for heapq
        return self.total_cost < other.total_cost

    def __repr__(self):
        # Used for debugging
        return str(self.pos)


def process_input(input_file_path):
    """
    Used to process input file into workable data
    :param input_file_path: path of input file
    :return: tuple of starting and goal positions, and a 2D array of the
robot workspace
    """
    try:
        input_file = open(input_file_path, 'r')
    except FileNotFoundError:
        print("File not found!")
        return
    first_line = input_file.readline()
    first_line_data = first_line.strip().split()
    start_pos = (int(first_line_data[0]), int(first_line_data[1]))
    goal_pos = (int(first_line_data[2]), int(first_line_data[3]))
    workspace = []
    for line in input_file:
```

```
        if line != "\n":
            curr_line = []
            nums = line.strip().split()
            for num in nums:
                curr_line.append(int(num))
            workspace.append(curr_line)
    input_file.close()
    workspace.reverse()
    return start_pos, goal_pos, workspace


def calculate_heuristic(curr_pos, goal_pos):
    """
    Calculate the h(n) value based on current and goal position
    :param curr_pos: tuple of current location
    :param goal_pos: tuple of goal position
    :return: The heuristic value calculated
    """
    return math.sqrt((curr_pos[0]-goal_pos[0])**2+(curr_pos[1]-
goal_pos[1])**2)


def is_valid_pos(pos, workspace):
    """
    Returns whether a position is valid (not out of bound and not blocked)
    :param pos: position to check
    :param workspace: 2D list of workspace
    :return: boolean of validity
    """
    if pos[1] < 0 or pos[0] < 0 or pos[1] >= len(workspace) or pos[0] >=
len(workspace[0]):
        return False
    return workspace[pos[1]][pos[0]] != 1


def calculate_angle_cost(curr_angle, new_angle, k):
    """
    Calculates the angle cost for changing direction based on curr_angle and
new_angle
    :param curr_angle: angle of current node in degrees
    :param new_angle: angle of next node in degrees
    :param k: penalty coefficient for direction change
    :return: angle cost as a float
    """
    delta_theta = abs(new_angle - curr_angle)
    if delta_theta > 180:
        delta_theta = 360 - delta_theta

    return k * (delta_theta / 180)


def calculate_distance_cost(curr_node, new_pos):
    """
    Calculates the distance cost to get to new_pos from curr_pos
    :param curr_node: coordinates of curr position
    :param new_pos: coordinates of new position
    :return: distance cost as a float
```

```
    """
    # Check if horizontal or vertical move
    if abs(new_pos[0] - curr_node.pos[0]) + abs(new_pos[1] -
curr_node.pos[1]) == 1:
        distance_cost = 1
    else:
        distance_cost = math.sqrt(2)

    return distance_cost


def calculate_step_cost(curr_node, new_pos, k):
    """
    Calculates the step cost by adding distance and angle costs
    :param curr_node: coordinates of curr position
    :param new_pos: coordinates of new position
    :param k: penalty coefficient for direction change
    :return: total step cost as a float
    :return: new angle in degrees
    """
    dx, dy = new_pos[0] - curr_node.pos[0], new_pos[1] - curr_node.pos[1]
    new_angle = math.degrees(math.atan2(dy, dx)) % 360

    if curr_node.parent is None:
        angle_cost = 0
    else:
        angle_cost = calculate_angle_cost(curr_node.last_angle, new_angle, k)

    distance_cost = calculate_distance_cost(curr_node, new_pos)

    return distance_cost + angle_cost, new_angle


def a_star_search_algo(start_pos, goal_pos, workspace, k):
    """
    Implementation of the A* search algorithm
    :param start_pos: starting coordinate
    :param goal_pos: goal coordinate
    :param workspace: workspace 2D list
    :return: None if no solution; curr_node, generated if solution is found
    """
    start_node = Node(start_pos, 0, calculate_heuristic(start_pos, goal_pos))
    reached = {start_pos: start_node.total_cost}
    frontier = []
    heapq.heappush(frontier, start_node)

    logging.info(f"Generated node:\t\t{start_node}")

    while frontier:
        # Get the smallest value
        curr_node = heapq.heappop(frontier)

        logging.info(f"Frontier popped:\t{curr_node}")

        # If solution is found
        if curr_node.pos == goal_pos:
            logging.info("======GOAL REACHED!!!======")
```

```
            logging.info("Reached: " + str(len(reached)))
            return curr_node, reached

        # Generate all child nodes
        for direction in DIRECTIONS:
            new_pos = (curr_node.pos[0] + direction[0], curr_node.pos[1] +
direction[1])

            # Append node to generated and frontier if it's valid
            if is_valid_pos(new_pos, workspace):
                step_cost, new_angle = calculate_step_cost(curr_node,
new_pos, k)
                child_path_cost = curr_node.path_cost + step_cost
                child_heuristic = calculate_heuristic(new_pos, goal_pos)
                child_total_cost = child_path_cost + child_heuristic
                if new_pos in reached and reached[new_pos] <=
child_total_cost:
                    continue
                child_node = Node(new_pos, child_path_cost, child_total_cost,
last_angle=new_angle, parent=curr_node)
                reached[child_node.pos] = child_node.total_cost
                heapq.heappush(frontier, child_node)

                logging.info(f"Generated node:\t\t{child_node}")
                logging.info(f"Added to frontier:\t{child_node}")


def calculate_output_values(final_node, workspace):
    """
    Function used to calculate several values needed for output
    :param final_node: The last node in the path found
    :param workspace: 2D list of the workspace
    :return: dictionary of all the values
    """
    # Just didn't want to change the original workspace
    new_workspace = copy.deepcopy(workspace)

    curr_node = final_node
    depth = -1
    moves = []
    f_values = []

    while curr_node:
        pos = curr_node.pos
        if new_workspace[pos[1]][pos[0]] != 2 and
new_workspace[pos[1]][pos[0]] != 5:
            new_workspace[pos[1]][pos[0]] = 4
        depth += 1
        f_values.append(curr_node.total_cost)

        if curr_node.parent is not None:
            direction = (curr_node.pos[0] - curr_node.parent.pos[0],
                         curr_node.pos[1] - curr_node.parent.pos[1])
            move = DIRECTIONS.index(direction)
            moves.append(move)

        curr_node = curr_node.parent
```

```
    moves.reverse()
    f_values.reverse()
    new_workspace.reverse()

    return {
        "depth": depth,
        "moves": moves,
        "f_values": f_values,
        "workspace": new_workspace
    }


def output_into_file(output: OutputModel, file_name):
    """
    Used to write all output data into a output file
    :param output: The OutputModel used to help with output generation
    :param file: the filepath of the output file
    :return: None
    """
    os.makedirs('Outputs', exist_ok=True)

    # Construct the full path
    output_file_path = os.path.join('Outputs', file_name)

    output_file = open(output_file_path, "w")

    print(output.depth, file=output_file)
    print(output.generated_nodes, file=output_file)
    print(output.moves, file=output_file)
    print(output.f_values, file=output_file)
    print(output.output_workspace, file=output_file)

    output_file.close()


def main():
    parser = argparse.ArgumentParser(description="Run A* search on a robot
workspace")
    parser.add_argument("input_file", type=str, help="Path to the input
file")
    parser.add_argument("k", type=int, nargs='?', default=0, help="Angle cost
penalty parameter (default: 0)")
    parser.add_argument("-o", "--output_file", type=str,
default="Output.txt", help="Name of the output file (default: 'Output.txt')")
    args = parser.parse_args()

    setup_logging(args.input_file, args.output_file, args.k)

    start_pos, goal_pos, workspace = process_input(args.input_file)
    result = a_star_search_algo(start_pos, goal_pos, workspace, args.k)
    if result:
        final_node, generated_nodes = result
        output_dict = calculate_output_values(final_node, workspace)
        output_dict["generated_nodes"] = generated_nodes
        output = OutputModel(output_dict)
        output_into_file(output, args.output_file)
```

```python
if __name__ == "__main__":
    main()
```

Program Output Files:

Input 1 K = 0:

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194
0 0 7 7 7 7 7 7 7 7 0 0 0 0 1 0 0 0 0 0 0 0 7 7 0 0 0 0 0 7 0
32.57299494980466 32.622776601683796 32.67572330035593 32.82509590207858
32.988682805403634 33.1684647227918 33.366774513857266 33.586369156128
33.830516434096076 34.103098247786185 34.40873160871375 34.413459741226546
34.41868167352756 34.4244787752596 34.43095126760845 35.006742657457565
35.02498060213621 35.045743124634214 35.06958612548419 35.097238938210836
35.12967631234924 35.16822857026841 35.214755041863 35.388346874966274
35.627416997969526 35.63911171640227 35.65536869969684 35.67945481172171
35.71862684627243 35.792417163603844 35.97056274847714 35.97056274847714
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Input 1 K = 2:

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0 0 7 7 7 7 7 7 7 0 0 0 0 1 0 0 0 0 0 0 0 7 7 0 0 0 0 0 7 0
32.57299494980466 32.622776601683796 32.67572330035593 33.32509590207858
33.488682805403634 33.6684647227918 33.866774513857266 34.086369156128
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37.02498060213621 37.045743124634214 37.06958612548419 37.097238938210836
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38.127416997969526 38.63911171640227 38.65536869969684 38.67945481172171
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Input 1 K = 4:

31
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0 0 7 7 7 7 7 7 7 7 7 0 7 7 7 0 0 0 0 0 0 0 0 0 0 0 1 1 1
32.57299494980466 32.622776601683796 32.67572330035593 33.82509590207858
33.988682805403634 34.1684647227918 34.366774513857266 34.586369156128
34.830516434096076 35.103098247786185 35.40873160871375 35.75290645585865
36.14213562373095 37.14213562373095 38.58573555203046 39.09507824507425
39.681834851628594 40.7025973741266 40.726440374976576 40.75409318770322
40.78653056184162 40.825082819760794 40.871609291355384 40.928780056167774
41.00054941671415 41.092980243349615 41.21572820569554 41.38477631085024
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0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 1 1 0 0 1 0 4 0 0 0 0 0 0 0 0 1 1 0 0 0 4 0 0 0 0 0 0 0 0 0 0 0 0 0
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0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Input 2 K = 0:

37
380
0 0 7 0 0 1 1 1 1 1 0 0 0 1 1 1 2 2 2 1 0 0 0 1 1 1 2 2 2 1 1 2 1 0 1 0
37.8021163428716 38.013511046643494 38.235341863986875 39.538997298749976
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Input 2 K = 2:

37
503
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48.01853433051622 48.284271247461895 48.60923954912998 49.0100924241513
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Input 2 K = 4:

37

674

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50.76901958965595 51.77681122334284 51.786530561841616 51.79898987322333
53.01853433051622 53.284271247461895 53.60923954912998 54.0100924241513
55.04415533044172 55.09955295296909 55.20390822051098 55.455844122715696
56.455844122715696 56.455844122715696

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Input 3 K = 0:

48

394

1 1 2 2 2 2 2 1 0 0 1 1 1 1 2 1 0 0 0 0 7 0 0 0 0 0 7 0 0 0 1 1 1 1 0 0 0 0 0 0 1 0 1 0 1 0 0 1

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0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Input 3 K = 2:

48
502
1 1 2 2 2 2 2 1 0 0 1 1 1 1 2 1 0 0 0 0 7 7 0 0 0 0 0 0 0 0 1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 1
46.51881339845203 46.602707673153105 46.69185152366881 47.79105474894765
48.40974558182222 49.048445851333845 49.707667325580374 50.38790881437237
51.047052213325614 51.592358377461835 51.63994136467273 52.299914698929804
52.47161725826807 52.656292164376524 52.85534862931096 54.133750523477666
54.87134969118418 55.38901530667865 55.40782558054147 55.42789428890646
55.44935062553747 56.620573423320565 57.34507664120184 57.89094512054433
57.94035690507799 57.99372694750279 58.0515354451702 58.11434067797518
58.18279485226897 58.25766375181925 58.33985122732316 58.94112549695428
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60.9558441227157 61.455844122715696 61.455844122715696 61.45584412271569
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0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Input 3 K = 4:

48
637
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46.51881339845203 46.602707673153105 46.69185152366881 48.29105474894765
48.90974558182222 49.548445851333845 50.207667325580374 50.88790881437237
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54.47161725826807 54.656292164376524 54.85534862931096 56.633750523477666
57.87134969118418 58.88901530667865 58.90782558054147 58.92789428890646
58.94935062553747 60.620573423320565 61.34507664120184 62.39094512054433
62.44035690507799 62.49372694750279 62.5515354451702 62.61434067797518
62.68279485226897 62.75766375181925 62.83985122732316 63.94112549695428
64.0585702391122 64.19616461169213 64.35920965178435 65.40046038195877
65.44810051389683 65.50368978394295 65.56931948749232 65.64784767501942
65.74326178322248 65.86124762152187 66.0100924241513 66.20211411065617
66.4558441227157 67.4558441227157 67.45584412271569 67.45584412271569
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